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Dynamics Explorer Guest Investigator

Final Report for

NASA Research Grant NAG 5-748

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Reporting Period
March 15, 1986 to June 30, 1988

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1. Review of Research Actions

Over the past two years the objectives of the proposal have generally been achieved. The research has focused upon using the SAI auroral images as a high resolution auroral precipitation input to the USU global scale ionospheric model. From the global scale modelling viewpoint, these images offer unique spatial and temporal resolution since all prior studies have used empirical auroral models. These latter models are devoid of storm, substorm or discrete oval features. The research focused on the problems in converting images to energy flux; using LAPI data to calibrate these energy fluxes; using the USU Time Dependent Ionospheric Model (TDIM) to look at the ionospheric consequences of this structure; and then using DE-2 in situ observations to compare with the TDIM ionospheric parameters.

In carrying out these studies, several additional investigations cropped up which were pursued to help meet the overall goals. The foremost difficulty in carrying out the TDIM modelling in conjunction with the high resolution DE auroral model was that of defining an appropriate ionospheric convection pattern. Under northward conditions this pattern is very complex. In order to study Theta aurora or in general northward IMF conditions, we required a new model. Hence, a study was completed to supply this new model to drive the TDIM as a function of the IMF. With the DE auroral model having adequate resolution to show structure on the 100's of km and all model electric fields being devoid of such structure, an investigation was pursued to find out the effect of structures in the electric field on the F-region.

During the grant period, five publications have been generated; 2 published, 1 submitted and 2 in preparation (see Appendix 1). Also during this period, presentations of this work were made at seven meetings including 2 international meetings, 1 AGU meeting and 4 DE science team meetings (see Appendix 2). Discussions with DE team members have been held at two other meetings and a 4 day trip was made to Iowa to meet with J. D. Craven and L. A. Frank to discuss the selection of suitable Theta auroral images.

2. Auroral Images: Application

As a result of the studies, the use of auroral images has been shown to be a crucial input to ionospheric (and thermospheric) models. Without such images only empirical representations of the auroral oval are available. Consequently, the ionospheric (thermospheric) models cannot progress beyond being climatic models without auroral image inputs. The community, however, still has problems with the conversion of auroral image intensities to auroral energy fluxes. This problem has been the topic of several discussions and data comparisons with Dr. M. Rees in Alaska. Although these problems still exist, the need for auroral images is crucial; indeed at the Vancouver, IUGG, 1987 meeting I presented a talk to show this (Appendix III contains the abstract for this talk). Using the software developed at USU, several more DE image sequences are being converted to DE auroral energy flux models for TDIM simulations.

3. Day 329, (25 November 1981) Study

This was the first study to use the SAI auroral images as an input to the TDIM model.

Images from a 3 hour segment of a DE-1 orbit were converted to auroral energy fluxes and characteristic energy. The SAI mode of operation on this day enabled 630 nm and 570 nm visible wavelength images as well as a UV auroral sequence to be obtained. On this day the 630 nm intensities were unusually bright, enabling significant spectroscopic information to be acquired. Unfortunately, although the images were ideal, the electric field information was too sparse for a good determination of the convection pattern to be made. Consequently, this first study was a relative study in which the DE auroral model was contrasted with the conventional empirical auroral oval model. The results showed how the spatial and temporal auroral structure lead to almost an order of magnitude difference in ionospheric F-region densities. More importantly, key F-region boundaries, i.e., trough edges, and polar hole locations, are all shifted by many degrees in latitude and longitude from those deduced by the empirical models. This work has been submitted for publication, see *Sojka et al.* [1987] in Appendix I.

4. Day 326, (21 November 1981) Study.

On this day the DE electric field data was able to constrain the convection pattern over a 24 hour period. The auroral images were available for each of 4 passes in this period. Although the day was generally undisturbed, an isolated sub-storm occurred during an image period. The model study involved using a conventional auroral model for the 24 hr period, and then by comparing the computed densities with L. Brace's electron density measurements showed that during the sub-storm period the model was significantly different. Then by introducing the DE image auroral model which contained the substorm dynamics, significantly improved results were obtained. However, this agreement was not perfect. Indeed as the auroral boundaries changed during the sub-storm, we were unable to change the convection electric field, and consequently obtained strong precipitation in a region of plasma stagnation. This led to unrealistically large F-region densities in the dusk sector auroral oval. Hence, the study demonstrates how important and closely tied the magnetospheric precipitation and convection are for ionospheric F-region modelling. This work was presented at the March 1988 DE science team meeting. It is currently being prepared for publication (see *Sojka et al.* [1988], Appendix I, paper number 4).

5. IMF Dependent Convection Model.

In order to use the TDIM to study periods when the IMF was not purely southward, a magnetospheric convection model was needed. Based upon published electric field data and DE results, such a model was developed (see Appendix 1, *Sojka et al.* [1986]). Independently of this work, *Heppner and Maynard* [1987] published an empirical model of the IMF dependent convection electric field. These two sets of models are quite different although they both appear to be consistent with the current published electric field data. In carrying out the study described in Section 4, both models were used; although, for that study they gave very similar results. In general, they lead to quite different ionospheric signatures. Work is underway with N. Maynard and L. Brace to understand these differences and by using L. Brace's ionospheric observations attempt to critically contract the two convection models.

6. Magnetospheric Structure in the High Latitude Ionosphere.

A question raised by using high spatial resolution auroral images is how important is it to also have high spatial resolution in the convection electric field? This question really addresses how the magnetospheric electric fields, currents and precipitation are coupled. At the present time, no global answer to this question exists. However, it was evident from the second DE-TDIM study, Section 4, that when precipitation boundaries move in a substorm, there must be a change in the electric field pattern. A first attempt at understanding how such structure in the electric field pattern affects the F-region was carried out by *Sojka and Schunk* [1988] (see Appendix 1). This work is critical for a better understanding of how to adjust convection electric field patterns in conjunction with high resolution auroral images. It should be noted again that high resolution in this context refers to structures on the 100–1000 km scale. This work is ongoing with the DE team.

7. Summary

The research carried out in this grant met most of the objectives set out in the proposal and included several additional studies that grew out of difficulties which had to be overcome in carrying out the studies. Sections 2 to 6 described the various studies carried out under this grant. In addition, results from Sections 3 and 4 are being prepared for publication in an ionospheric conductivity study. This work will also highlight the need for auroral imagery for E-region problems (see Appendix 1, paper number 5).

The objectives set out in the proposal were, in general, met with the exception of a Theta aurora study. This problem is still being worked on. However, the general consensus in both the DE team and the community at large is that both the convection pattern and precipitation pattern are ill defined to the point that agreement on how to constrain these inputs is currently not available. I spent four days in Iowa with Dr. Frank's group looking at Theta aurora images. A subset was selected for a TDIM study. However, I now need to work with J. Heppner and N. Maynard to find a realistic convection pattern.

The various studies carried out under this grant have revealed just how important coupling between the auroral and convection structure is, as well as how important the real structure is over the smooth empirical models. In order to achieve a predictive or weather modelling ionospheric (or thermospheric) capability these points must be addressed.

References

Heppner, J. P. and N. C. Maynard, Empirical high-latitude electric field models, *J. Geophys. Res., 92*, 4467, 1987.

Appendix I—DE Papers

1. An interplanetary magnetic field dependent model of the ionospheric convection electric field, J. J. Sojka, C. E. Rasmussen, and R. W. Schunk, *J. Geophys. Res.*, *91*, 11281–11290, 1986.

2. Modeled F-Region Response to auroral dynamics based upon dynamics explorer auroral observations, J. J. Sojka, R. W. Schunk, J. D. Craven, L. A. Frank, J. Sharber and J. D. Winningham, *J. Geophys. Res.*, submitted, 1987.

3. A model study of how electric field structures affect the polar cap F region, J. J. Sojka and R. W. Schunk, *J. Geophys. Res., 93*, 884–896, 1988.

4. Theoretical study of the high latitude F-region based upon dynamics explorer measurements on the 22 November, 1981, J. J. Sojka, M. D. Bowline, R. W. Schunk, J. D. Craven, L. A. Frank, J. P. Heppner, L. Brace, J. Sharber, D. Winningham and M. H. Rees, *J. Geophys. Res.*, in preparation.

5. Comparison of ionospheric conductivities deduced from DE auroral images and those computed from an ionospheric model, J. J. Sojka, C. E. Rasmussen, J. Craven, and L. A. Frank, *J. Geophys. Res.*, in preparation.

Appendix II—DE Presentations

1. COSPAR, Toulouse; July 1986; presented "Ionosphere's response to an auroral storm based upon the Dynamics Explorer SAI and LAPI data bases."
2. DE science team meeting; November 1986; presented "Initial ideas for the study of 20–1000 km scale polar cap structures using DE data and the TDIM model."
3. DE science team meeting; February 1987; presented "How electric field "structures" impact smooth F-region model calculations".
4. IUGG, Vancouver 1987, presented "Global scale auroral imagery, an essential tool for ionospheric simulation and prediction."
5. DE science team meeting, September 1987; presented "Ionospheric consequences of a 2-D small scale auroral form in the polar cap."
6. AGU fall meeting San Francisco, December 1987; presented "A model study of how electric field structures affect the polar cap F-region."
7. DE science team meeting, March 1988; presented "2nd DE-ionospheric model study."

Appendix III—IUGG, Vancouver 1987, Presentation

Global Scale Auroral Imagery, an Essential Tool for Ionospheric Simulation and Prediction

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With the availability of global scale auroral image sequences it has been possible to introduce auroral dynamics into global scale ionospheric simulations. The combinations of simultaneous images at different wavelengths enables the magnetospheric auroral precipitation pattern to be derived as a function of both space and time. This dynamics in a global scale cannot be obtained by other means. Since global models of the ionosphere are sensitive to this temporal and spatial variability (on the scale of $\sim$ 100 km and 10's of minutes), the images become an essential tool for these simulations.

In this paper we will present examples of the sensitivity of the ionospheric models to the spatial and temporal variability. The current shortcomings in this procedure will be discussed both from the observational and modelling point of view. Why this image capability is an integral aspect of future real time ionospheric modelling and prediction is also considered.